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AN EMERGENCY DENTAL KIT ENCASEMENT FOR USE ON EXTRATERRESTRIAL MISSIONS

JACK H. FERGUSON, B.S.

JACK L. HARTLEY, Lieutenant Colonel, DC, USAF

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USAF School of Aerospace Medicine
Aerospace Medical Division (AFSC)
Brooks Air Force Base, Texas

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FOREWORD

This report was prepared in the Systems Research Laboratories, San Antonio, Texas, under task No. 775303, contract No. AF 41(609)-2724. The work was initiated on 24 January 1966. The paper was submitted for publication on 27 January 1966.

The plastics used in the study and the manufacturers are as follows: polycarbonate (Lexan) by General Electric, ABS (acrylinitrile-butadiene-styrene) (Cycoloc) by Marbon, polyethylene (Marflex) by Phillips Petroleum, acrylic by DuPont Chemical Co., polyester resin Fiberglas by Cook Chemical Co. and Ferro Corporation, urethane foam (Corofoam) by Cook Chemical Co., and urethane foam (Nopcofoam) by Nopco Chemical Co.

This report has been reviewed and is approved.

Harold V. Ellingson
HAROLD V. ELLINGSON
Colonel, MC, USAF
Commander

PREFACE

The purpose of this investigation is to develop a suitable inclosure for the instruments, materials, and drugs which have been determined to be necessary for emergency "buddy" dental care during prolonged space flight.

The approach was to obtain, by contract, a most suitable material which must be strong, compact, lightweight, and nontoxic in an altered environment. The kit should retain the contents securely and permit the selection and return of individual items as necessary.

Work is continuing on methods of storage in the space vehicle, on the selection of methods of opening and closing the kit, and on the determination of a suitable color so as to indicate its emergency nature.

The contents of the kit, with modifications as necessary, will be presented in a subsequent report after an adequate trial of the items currently proposed.

Use of an inclosure for a basic dental-treatment kit has been suggested for isolated bases, remote sites, mass casualty situations, field and missionary operations for treatment by trained personnel. This initial report is, therefore, presented for use by others who may have a similar requirement to provide dental care under unusual circumstances.

ABSTRACT

Steps have been taken to construct an emergency dental kit for "buddy" or self-care during prolonged space flight. Initial steps taken included a material study, material selection, a design study, prototype design, and destructive testing of a model. Also included is an explanation of the properties of Lexan and Nopcofoam, the materials selected, as well as of the other materials considered. A design based on sandwich construction has been developed and the characteristics of this design are summarized.

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I. INTRODUCTION

A study of the controlling factors necessarily precedes the fabrication of an emergency dental kit for aerospace use. Steps taken in the material and design study include reviewing the pertinent requirements, analyzing data available on plastic material, selecting appropriate materials, and designing the container. A model, in accordance with prototype specifications, has been constructed from plastic material to provide additional data. The data were obtained from destructive testing of the model. Results of the investigation of suitable materials and kit design are presented. They form the basis for the construction of a prototype that is to be a tentative solution to the requirement. Alterations will be made as necessary to comply with the exacting demands of space flight.

II. MATERIAL AND DESIGN STUDY

Key parameters

Material and design studies were based on certain key parameters which are the primary limiting factors in constructing the kit. The unique environment of space requires the case to survive the high G forces of insertion and perhaps re-entry. In addition, orbital G forces, classically called zero G are very small; hence, when the case is uncovered, it must retain all items in their proper places. As the space cabin atmosphere is closely controlled, all materials utilized must be gas-free or nontoxic under conditions of reduced pressure. Moreover, since the entire unit must be lifted from earth to orbit, weight is a very important consideration.

Secondary limitations involve color that will contrast with other space cabin equipment, sterilization of kit and contents prior to the mission, removal and reinsertion of instruments, frequency of use, and probable storage life.

Finally, for time and economic considerations, the chosen material must be currently available.

Materials considered

Plastic material was investigated because of the apparent savings in weight. It may be formed at relatively low temperatures and with comparatively simple forms. The design material must be strong enough not to deform under extended load. Physical characteristics determined by established deformation technics for nonelastic materials may only be used as an initial guide. The viscoelastic behavior of plastics requires that actual performance tests be conducted on finished products to ensure that they meet all the criteria established.

Two types of polyurethane foam were studied, as were five types of material for the high-strength, or load-carrying portion of the case. Corofoam, which uses Freon, and Nopcofoam, which is water-activated, were the foam materials considered. The high-strength materials studied included polyester reinforced with Fiberglas, acrylic sheet, linear polyethylene sheet, acrylonitrile-butadiene-styrene, and polycarbonate sheet. Table I shows the relative merit of the materials considered.

Corofoam, used very widely, was the first foam to be considered. It adheres well to polyester resin and has good physical properties in

a very light density. Corofoam has one serious limitation, however, which precludes its use in this application; it uses Freon 11 and Freon 12 during the formation of the cellular structure from the basic materials. The Freon takes part in the reaction and then remains as a halocarbon which is approximately 90% of the volume of the closed cells. The Freon, or an equivalent gas, is essential to the reaction with the isocyanate in Cook's process. To avoid all possibility of toxicity, Corofoam was eliminated as were all other foams that are based on this type of reaction.

Nopcofoam was also considered. It is a water-based foam. Water is used as the blowing agent to react with the isocyanate and forms CO_2 which creates the cellular structure. The carbon dioxide rapidly diffuses out of the foam. Loss of this gas is detrimental to the insulation qualities of the material. Since insulation was not a critical consideration, the other properties were evaluated. Strength calculations show that Nopcofoam as a core is sufficiently strong to be used with any thermoset (Fiberglas reinforced) or thermoplastic material in this design. Furthermore, it has excellent adhesion qualities and may be adapted to use with any of the other materials used. As a last consideration, Nopcofoam has been used in the padding in the astronauts' chairs, which indicates its acceptability for space flight.

Polyester reinforced with Fiberglas was the first material considered for the outer laminate or high-strength layer. This material is used extensively at present in making "sandwich"

TABLE I

Properties of plastics

	Lexan*	Cycolac*	Marflex*	Acrylic	Polyester resin*	Corofoam*	Nopcofoam*
Relative merit	1	2	3	4	5	II	I
Toxicity	A	A	†	‡	§	**	A
Strength/weight ratio	A	B	C	C	A	A	A
Previous space use	Yes	Yes	No	No	No	No	Yes
Moldability	B	A	B	B	B	A	A
Dimension stability	A	B	B	B	B	B	B
Chemical resistance	A	B	A	B	C	N/A	N/A
Temperature resistance	A	B	C	C	B	A	A
Bondability	A	A	C	B	A	A	A
Mold shrinkage	A	A	C	C	B	N/A	N/A
Material strength	B	B	C	B	A	C	C
Light weight	B	B	B	C	C	A	A
Machinability	A	B	B	B	C	N/A	N/A
Flammability	No	††	††	††	††	††	††
Colors available	A	A	B	B	C	N/A	N/A

A = excellent; B = good; C = acceptable.

*Polycarbonate (Lexan), ABS (acrylinitrile-butadiene-styrene (Cycolac), polyethylene (Marflex), Polyester resin reinforced with Fiberglas, urethane foam (Corofoam), urethane foam (Nopcofoam).

†Good documentation but not previously used.

‡Could not be recommended by DuPont.

§Minimum uncured resin (2%).

**Closed cells contain fluorocarbon.

††Slow burning.

panels. The Fiberglas reinforcement does not present a problem with regard to toxicity, and the finished laminate has adequate strength. There are, however, problem areas which rule out this approach. The first is toxicity. Present technics do not completely cure polyester resins. At best, there is still approximately 2% unreacted monomers which may be irritating if given off as gas. Fabrication technic does not allow fine-mold detail to be attained, and where the detail is accomplished, the Fiberglas probably will not be present as a reinforcement. As a final consideration, vacuum-forming technics do not allow the removal of all excess resin. This results in an overall weight that would be 20% to 50% higher than can be obtained with thermal sheet. One final difficulty is in the toxicity information available. Several polyester manufacturers have indicated by personal communication that they cannot provide information on the toxicity of polyesters.

Acrylic sheet was considered very early in the study. Several large manufacturers, including DuPont, have many varieties of acrylic available. The mechanical properties are acceptable in general, but resistance to heat is not as good as other materials available. Moreover, acrylic sheet is not as predictable in vacuum-forming operations as some other preferred plastics. Toxicity information from DuPont indicated that they could not affirm that acrylics would remain nontoxic under space-flight conditions.

Linear polyethylene could be used for the outer laminate layer, but it is not preferable to either polycarbonate or acrylonitrile-butadiene-styrene. The polyethylene is not as acceptable for several reasons. For one thing, the strength-to-weight ratio is not as high as the other two plastics mentioned. In addition, it does not allow equal bonding strengths in sandwich construction. Although many experiments attest to its nontoxicity, it is not a proven product for space use. On the other hand, the physical properties are good, its rigidity is excellent, and it withstands heat well. Should molding problems arise with the chosen material during prototype fabrication, this material could be an acceptable alternate.

Acrylonitrile-butadiene-styrene (ABS) is an alternate for the outer laminate, should unforeseen reasons preclude the use of a polycarbonate. ABS materials have been previously used in space flight. They provide an excellent bonding surface for foam-core structures and are second only to polycarbonate material in strength-to-weight ratio. Vacuum-mold characteristics are extremely well defined, and cooling effects after forming are small. This thermosheet is available in a wide selection of physical properties and colors.

The most appropriate material considered appears to be a polycarbonate. The particular material chosen for prototype evaluation is called Lexan. It has been previously used in space flight. It is nontoxic and adaptable to vacuum-forming. Lexan has the highest strength-to-weight ratio of any thermoform plastic considered. It is very heat-resistant and will withstand a wide variety of chemical solutions. It should allow the closest attainment of the empty-case design goal of 450 gm.

Design considerations

Fabrication methods applicable to the formation of solid objects of irregular form as opposed to sheet or bar stock include injection molding, sheet forming, and normal machining operations. Injection molding as was previously discussed in a proposal by the Systems Research Laboratories is not acceptable for this project. Injection molding would be prohibitively expensive and would not allow any modification of design at an intermediate stage of development. Hand-machining each container is not practical either because of the time involved. The choice of sheet-forming, using vacuum assists, was verified to be technically preferable.

One feature of vacuum-forming should be noted at this point. Although studies have been conducted, accurate prediction of the final thickness and molecular structure can not be made when a thermal sheet is drawn over an irregular surface. To name but a few of the variables, one must include the time to heat the sheet, the spectrum of the heat source, the

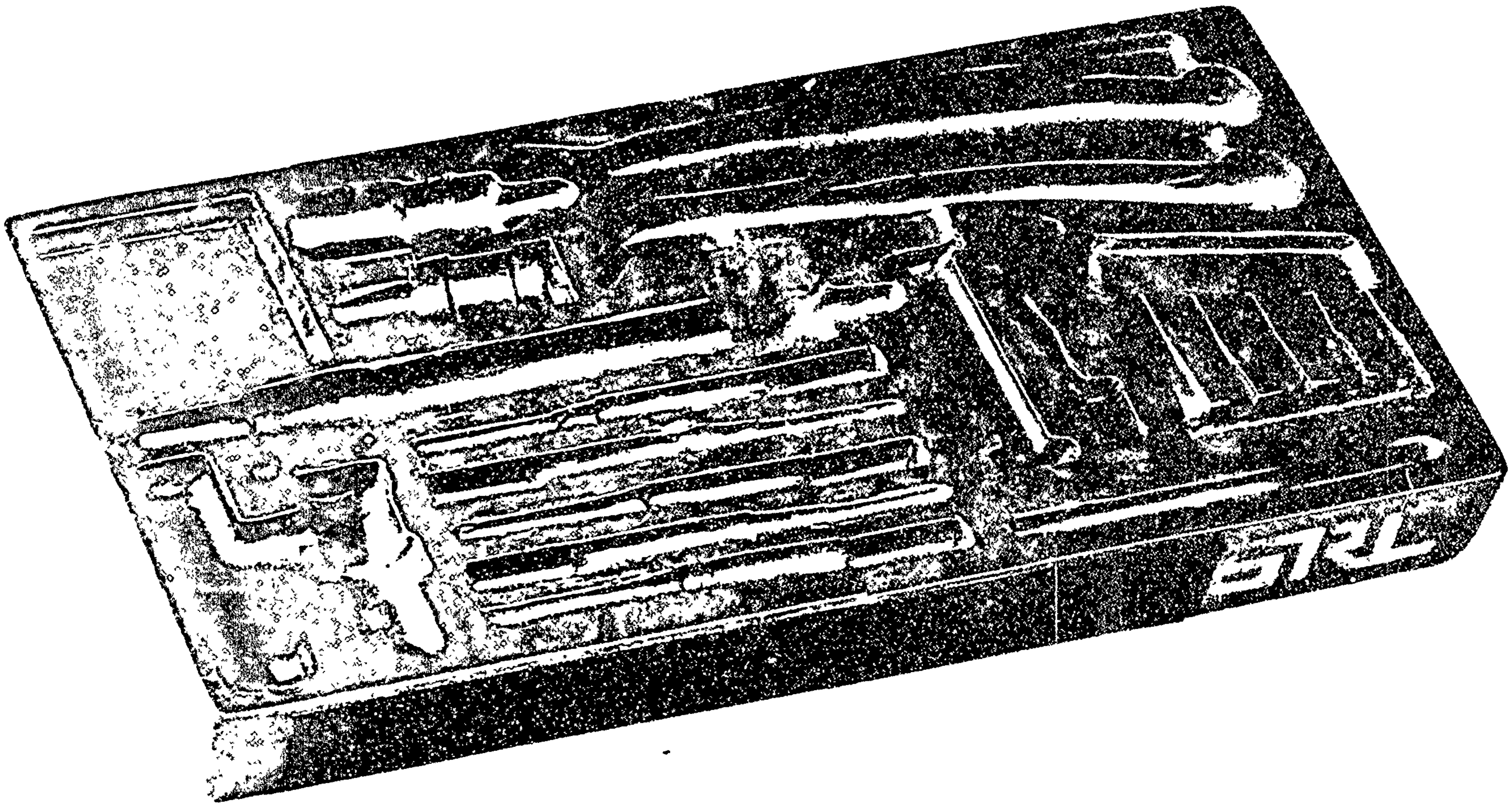

FIGURE 1

Model prototype case. Optimum construction consists of the use of a sandwich-material design of low- and high-density plastics. This design provides an excellent strength-to-weight ratio with an overall low weight. Advantages of the design were verified by construction and destructive testing of a container shell of this type made of comparable plastics.

temperature of the mold, the time taken to draw the plastic, the interrelationships of the mold cavities, the past history of the plastic to be formed, the moisture present, and the rate at which the vacuum is applied. Thus, while a particular material may be preferable in theory, not until actual performance tests have been conducted may it safely be concluded that a particular material is completely acceptable.

On completion of the study, it was decided to begin construction of a model and by this means arrive at a solution for a final design to the developmental problems. The model would demonstrate the correlation between engineering design and manufacturing approximations. Adequate specifications and detail drawings were completed to described the responsibility of the manufacturer. These papers are not the limit of contact between Systems Research Laboratories and Hill Manufacturing Company, because continuing supervision and technical assistance were foreseen to be necessary during the manufacturing process. The specifications and drawings did, however, form the basis for the fabrication of a model (fig. 1) which permitted collection of important data. Experience in fabrication of this model and incorporation of a different instrument from the original set indicates that a few dimensions of the original design will be revised.

The prototype container is now under construction with a few minor revisions incorporated as determined by the results of destructive testing of the model and consultations with the project monitor. Thus, the specifications are considered sufficiently complete to adequately meet all requirements except the mounting position and final container color. The prototype container based on these specifications will allow the Dental Sciences Division (USAF SAM) to make a complete evaluation of the material and design concept chosen.

III. FUTURE CONSIDERATIONS

In view of the results obtained from the material study, a polycarbonate by General Electric Company called Lexan and a Freon-free foam called Nopcofoam seem to be the most suitable for constructing the case. These materials are readily formed and should give adequate strength. Furthermore, they have been previously utilized in space flight.

Although Lexan has been chosen as the primary material for development of the prototype, it must be remembered that plastic materials are not as predictable in behavior as nonplastics. Therefore, possible alterations must be considered and may become necessary should Lexan thin excessively or should other problems arise in the manufacturing of the kit. The dental kit should be tested thoroughly both nondestructively and then destructively for adequate performance.

A combination of polyester and Fiberglas for the outer laminate layer no longer appears to be suitable because the polyester resin does not cure completely. The gases given off under postcuring, reduced pressure, or other unusual conditions, are irritating to personnel. Other foams in the low-density range were considered unsuitable because they encapsulate fluorocarbons which may leak out under reduced external pressures.

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